Aviation Investigation Final Report

Location:	Lincoln, California	**Accident Number:**	WPR14TA370
Date & Time:	September 4, 2014, 20:05 Local	**Registration:**	N217HP
Aircraft:	Eurocopter AS 350 B3	**Aircraft Damage:**	Substantial
Defining Event:	Loss of engine power (partial)	**Injuries:**	2 None
Flight Conducted Under:	Public aircraft		

Analysis

The purpose of the public helicopter flight was to provide recurrent emergency procedures and night vision goggle training for the commercial pilot. Both the pilot and the flight instructor were active pilots for the law enforcement agency and current in the accident helicopter type.

Preflight checks and initial training maneuvers were uneventful. During the power recovery phase of a practice autorotation, the flight instructor applied engine power by moving the throttle twist grip from the idle to the flight position; however, the engine did not respond as expected, the rotor rpm decayed, and the helicopter landed hard. The helicopter sustained substantial damage to the tailboom; neither occupant was injured.

Immediately following the hard landing, the flight instructor observed that the rotor rpm was still low and that the amber-colored governor and twist grip warning lights, which should have extinguished during the power recovery, were still illuminated. He manipulated the throttle twist grip multiple times between the idle and flight detents in an attempt to extinguish the lights and increase the rotor speed without success. With the twist grip in the "flight" position, he then reached up and recycled the start selector switch on the roof panel, and the lights extinguished. After the flight instructor exited the helicopter and examined the damage, he got back in the helicopter, and the pilot then shut down the engine.

This was the first training flight (requiring an autorotation with power recovery) since the helicopter manufacturer had issued a service bulletin (SB), which recommended modifying the engine control logic. The SB was issued following multiple reports of engines remaining at idle power during practice autorotation power recoveries despite the twist grip being moved to the "flight" position. Although this was similar to the accident scenario, maintenance records revealed that the SB was accomplished about 46 flight hours before the accident, and postaccident examination revealed that the SB had been complied with correctly.

During the postaccident airframe examination, a small amount of play was observed in the twist grip on the flight instructor's side, which sometimes caused the governor and twist grip amber caution lights to not extinguish when the grip was in the flight detent. Wiggling the twist grip while in the flight detent resolved the issue, which the operator's chief pilot reported was not uncommon throughout the agency's fleet, and the pilots were accustomed to it. The flight instructor did not recall the status of the amber lights during the recovery phase before the hard landing. The flight procedures for autorotation training called for a confirmation that these lights were extinguished during the power recovery phase; however, the chief pilot stated that, given the minimal altitude (70 ft above ground level [agl]) that was recommended by the helicopter's manufacturer to initiate the power recovery, pilots were taught to focus on flying the helicopter and not on the lights.

Ten months after the accident, the helicopter manufacturer issued a safety information notice regarding simulated engine-off landing training, which referenced the high exposure to accidents and incidents during engine-off landings, and issued a series of procedural updates, including advising that power recoveries be initiated as the helicopter passed through 200 ft agl rather than 70 ft agl.

The status of the lights during the maneuver could not be determined; however, if they were illuminated, the engine would have been operating in "mixed" mode and would have exhibited a very slight delay in power recovery. A postaccident engine run revealed that the engine responded within specifications in mixed mode and in a series of other modes under multiple load conditions. Following the run, the engine's hydromechanical unit was removed and tested. It was slightly outside of specification for the "P3" module check, which affected operation in mixed mode. However, because the engine test run was successful, this adjustment variance was not considered causal to the engine providing insufficient power during the accident sequence. Additionally, the engine manufacturer stated that it was not unusual for this module to go out of adjustment in the field.

A failure-mode analysis was performed in an effort to determine why the engine would not resume flight power after the hard landing and whether this was related to the engine's failure to provide sufficient power when commanded by the pilot during the power recovery phase of the practice autorotation. The results revealed that the behavior could be duplicated if the throttle input lever had become declutched from the load limiter inside the hydromechanical unit. However, for this condition to have occurred, the pilots would had to have performed a highly unusual series of nonstandard procedures before the accident. It is also possible that, if declutching occurred, it could have been caused by the hard landing, in which case, it would not explain what happened in the accident. Therefore, the reason that the engine did not provide sufficient power when commanded by the pilot during the power recovery phase of the practice autorotation could not be determined.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

The failure of the engine to provide sufficient power when commanded by the pilot during the power recovery phase of a practice autorotation for reasons that could not be determined because postaccident

examination revealed no mechanical malfunctions or failures that would have precluded normal operation.

Findings

Not determined	(general) - Unknown/Not determined

Factual Information

History of Flight

Autorotation	Miscellaneous/other
Landing-flare/touchdown	Loss of engine power (partial) (Defining event)
Landing-flare/touchdown	Loss of control in flight
Landing-flare/touchdown	Hard landing

On September 4, 2014, at 2005 Pacific daylight time, a Eurocopter AS 350 B3, N217HP, landed hard during a practice autorotation at Lincoln Regional Airport/Karl Harder Field, Lincoln, California. The helicopter was registered to and operated by the California Highway Patrol (CHP) as a public aircraft, training flight. The commercial pilot and flight instructor (CFI) were not injured. The helicopter sustained substantial damage during the accident sequence. The local flight departed Auburn Municipal Airport, Auburn, California, about 1952. Visual meteorological conditions prevailed, and no flight plan had been filed.

The purpose of the flight was to provide recurrent emergency procedure and night vision goggle (NVG) training for the pilot, who was positioned in the right seat. Prior to departure, the crew discussed the plans for the flight, and the pilot performed a preflight inspection. The decision was made to perform a full landing at Lincoln, followed by a practice autorotation with power recovery, and then once ambient light had diminished, transition into NVG training. Because they departed during daylight the pilot turned off the NVG unit's battery pack, and moved the goggles to the up position on his helmet.

Once the startup and departure checklists were complete, the CFI, who was positioned in the left seat, conducted a throttle check in accordance with the autorotation training before take-off check list. He ran the engine to full power while stationary on the helipad, and then rolled the twist grip to idle (MIN position), and received confirmation that the low RPM horn was functioning. The engine stabilized at idle power, and he then rolled the twist grip up to flight (VOL position). Both the amber governor (GOV) and twist grip (TWT GRIP) caution lights extinguished, and the engine responded appropriately by reaching full power RPM within about nine seconds.

With all systems normal, they departed, and the pilot performed an uneventful landing on Runway 15 at Lincoln. They then departed to practice the autorotation on the same runway. The CFI stated that he was the sole manipulator of the throttle twist grip throughout the flight, and that he instructed the pilot to pay attention to work on attaining the appropriate rotor and airspeeds rather than focusing on a specific landing spot. Once they were both ready, the CFI rolled the twist grip to the MIN position to initiate the maneuver. The pilot lowered the collective and the helicopter descended; once they reached an altitude of about 50 feet above ground level (agl), the pilot began to initiate the flare, with the CFI countering by rolling the twist grip back to the VOL position. They heard the engine respond along with an accompanying yaw motion, and the CFI announced "power recovery."

The pilot stated that he held the helicopter in the flare about 25 ft agl, and the rotor speed started to

increase, so he pulled up lightly on the collective control to prevent a main rotor overspeed. The helicopter then "ballooned" slightly, and he lowered the collective to recover. The forward speed decayed, and he moved the helicopter forward in anticipation of the hover. As he started to raise the collective control, the low rotor speed horn sounded and the helicopter began to rapidly descend. He pulled up the collective in an effort to arrest the descent, and the helicopter hit the ground hard. His NVG goggles flipped down over his eyes, and his forward vision became effectively blocked. He then perceived forward and nose-low motion as the CFI took control of the helicopter. He felt the cyclic pull full aft, and the helicopter came to rest.

Once on the ground, the CFI pushed down on the collective and the rotor speed returned to about 360 RPM, which was below the normal operating speed range indicated on the RPM gauge. He then noticed that the amber governor (GOV) and twist grip (TWT GRIP) caution lights were still on. He looked down and confirmed the twist grip was in the VOL detent and against the stop. He then tried to move it, confirming that it was fully against the stop. He then "jiggled" the control in an attempt to extinguish the caution lights, stating that in his experience the lights do not always immediately extinguish. Again they did not turn off, so he rolled the twist grip down to IDLE, and then back to VOL, but the rotor RPM again stopped short below the green arc of the normal operating RPM range, at about 360 RPM.

He then reached over to unlock the twist grip locking device ("gate") on the pilot's side, with the intention of manually controlling fuel flow to the engine. He did so, rotated the twist grip, and the engine RPM increased slightly. He then decided to discontinue further troubleshooting steps.

With the twist grip back in the VOL detent, he reached up to the start selector switch in the roof panel, and turned it to IDLE, and then back to FLT, at which time the amber warning lights extinguished. He then then asked the pilot to take the controls, and he exited the helicopter to examine if any damage had occurred.

Examination revealed that the tailboom had bent downwards at its intersection with the aft bulkhead, just below the engine exhaust outlet. The aft bulkhead sustained wrinkling damage, and the skids had spread, bending both aft landing skid support tubes. The CFI got back into the helicopter and the pilot initiated an engine shutdown. Both pilots reported that at no time in the flight did they see the red GOV warning light illuminate.

Flight instructor Information

Certificate:	Commercial; Flight instructor	**Age:**	44,Male
Airplane Rating(s):	None	**Seat Occupied:**	Left
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	4-point
Instrument Rating(s):	Helicopter	**Second Pilot Present:**	Yes
Instructor Rating(s):		**Toxicology Performed:**	No
Medical Certification:	Class 2 Without waivers/limitations	**Last FAA Medical Exam:**	January 16, 2014
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	August 27, 2014
Flight Time:	3943 hours (Total, all aircraft), 2943 hours (Total, this make and model), 3250 hours (Pilot In Command, all aircraft), 90 hours (Last 90 days, all aircraft), 79 hours (Last 30 days, all aircraft), 0 hours (Last 24 hours, all aircraft)		

Pilot Information

Certificate:	Commercial	**Age:**	37,Male
Airplane Rating(s):	None	**Seat Occupied:**	Right
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	4-point
Instrument Rating(s):	Helicopter	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	Class 2 Without waivers/limitations	**Last FAA Medical Exam:**	February 28, 2014
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	June 14, 2014
Flight Time:	2988 hours (Total, all aircraft), 2635 hours (Total, this make and model), 2938 hours (Pilot In Command, all aircraft), 71 hours (Last 90 days, all aircraft), 42 hours (Last 30 days, all aircraft), 2 hours (Last 24 hours, all aircraft)		

Both crew members were full-time active pilots for the CHP.

The flight instructor held a commercial pilot certificate with ratings for helicopter, instrument helicopter, along with a flight instructor certificate with ratings for helicopter. He reported a total flight time of 3,943 flight hours, with 2,943 as pilot-in-command in the accident make and model, and 79 hours in the 30 days prior to the accident. His most recent flight review took place on August 27, 2014, and was performed in the accident make and model.

The pilot held a commercial pilot certificate with ratings for helicopter and instrument helicopter. He reported a total flight time of 2,988 flight hours, with 2,635 as pilot-in-command in the accident make and model, and 42 hours in the 30 days prior to the accident. His most recent flight review took place on June 14, 2014, and was performed in the accident make and model.

Aircraft and Owner/Operator Information

Aircraft Make:	Eurocopter	**Registration:**	N217HP
Model/Series:	AS 350 B3	**Aircraft Category:**	Helicopter
Year of Manufacture:	2002	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	3628
Landing Gear Type:	Skid	**Seats:**	3
Date/Type of Last Inspection:	July 22, 2014 Continuous airworthiness	**Certified Max Gross Wt.:**	4961 lbs
Time Since Last Inspection:	12 Hrs	**Engines:**	1 Turbo shaft
Airframe Total Time:	10152 Hrs as of last inspection	**Engine Manufacturer:**	Turbomeca
ELT:	C126 installed, not activated	**Engine Model/Series:**	Arriel 2B
Registered Owner:	CALIFORNIA HIGHWAY PATROL	**Rated Power:**	871 Horsepower
Operator:	CALIFORNIA HIGHWAY PATROL	**Operating Certificate(s) Held:**	None

The helicopter, serial number 3628, was manufactured in 2002 and equipped with a Turbomeca Arriel 2B engine. The helicopter was maintained under a continuous airworthiness program, and the last inspection occurred twelve flight hours prior to the accident.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Dusk
Observation Facility, Elevation:	KLHM,121 ft msl	**Distance from Accident Site:**	0 Nautical Miles
Observation Time:	03:15 Local	**Direction from Accident Site:**	
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	5 knots /	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	220°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.64 inches Hg	**Temperature/Dew Point:**	26°C / 6°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	AUBURN, CA (AUN)	**Type of Flight Plan Filed:**	None
Destination:	Lincoln, CA (LHM)	**Type of Clearance:**	VFR
Departure Time:	19:52 Local	**Type of Airspace:**	Class G

Airport Information

Airport:	LINCOLN RGNL/KARL HARDER FIELD LHM	**Runway Surface Type:**	Asphalt
Airport Elevation:	121 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	15	**IFR Approach:**	None
Runway Length/Width:	6001 ft / 100 ft	**VFR Approach/Landing:**	Simulated forced landing

Wreckage and Impact Information

Crew Injuries:	2 None	**Aircraft Damage:**	Substantial
Passenger Injuries:		**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	2 None	**Latitude, Longitude:**	38.909168,-121.351387(est)

Tests and Research

Engine Control Operating Principles

The engine is controlled by the pilot through a set of guarded starting and mode selector switches on the overhead instrument panel, and a twist grip on the collective pitch lever. The start selector has an "IDLE" position for engine autostart and ground idle, and a "FLT" position which is selected for flight.

The mode selector has both an "AUTO", and "MAN" position. In AUTO mode, the digital engine control unit (DECU) controls the hydro mechanical unit's (HMU) fuel metering system by utilizing a series of external input parameters such as collective pitch angle (anticipator), engine speeds, and atmospheric conditions.

In AUTO mode engine power is set to flight by rotating the twist grip to the VOL detent, and idle by selecting the MIN position. In AUTO mode, the twist grip remains in the VOL position for normal operation. The MIN position is used for training purposes only, and switching to ground idle under normal operations is accomplished by setting the overhead start selector switch to IDLE.

In MAN mode, the red GOV light illuminates, and modulation of engine power is performed by the pilot, by rotating the center (pilot side) twist grip past the stop, after unlocking its gate. If the automatic governing system fails, the red GOV light is illuminated, and the fuel metering needle in the HMU is

frozen. The pilot can then control the fuel flow manually by rotating the twist grip.

During the power recovery phase of autorotation training, the pilot is directed to move the twist grip from MIN to VOL, thereby relinquishing full engine control to the DECU, which commands flight power. The electrical control logic in the twist grip system mechanism is designed such that flight power is commanded by the DECU as soon as the twist grip moves out of the IDLE detent (releasing the "forced-idle" microswitch), prior to it engaging the VOL detent. In this "mixed" mode, both the amber GOV and TWT GRIP lights are illuminated, and the position of the fuel metering needle is governed by the DECU. Movements of the metering needle by manual control are compensated by an internal stepper motor (until it reaches its mechanical stops). Full engine power is still available in mixed mode, however the engines reaction time to external load changes is reduced.

Examinations

Following the accident, the helicopter was examined by the NTSB investigator-in-charge (IIC), along with technical representatives from Airbus Helicopters and Turbomeca, and the CHP Chief Helicopter Pilot.

Throttle Functional Check

A functional check of the center (pilot) throttle twist grip revealed that when in the MIN position, the TWT GRP and GOV amber caution lights were on, as expected. Rotation to the VOL position resulted in the lights extinguishing, as expected.

A similar functional check was performed on the left twist grip, which was used by the CFI. It was found that when moving from the MIN to VOL position, the grip could be moved past the VOL detent, causing the TWT GRP and GOV amber caution lights to briefly extinguish, and then illuminate again once the detent stop was positively reached. Easing the grip back caused the lights to extinguish. According to the CHP Chief Helicopter Pilot, this was not uncommon throughout their AS350 fleet, and all pilots knew that sometimes the grip needed to be "wiggled" in its detent at the VOL position, for the lights to be extinguished. A functional check was performed on a similarly equipped CHP sister-ship, with the same results, except that more force was needed to induce the same "over center" result on the left twist grip.

Rotor Control System Alert Service Bulletin

Maintenance records revealed that this was the first training flight (and thereby practice autorotation) since mandatory Alert Service Bulletin (ASB) AS350 - 67.00.43 had been accomplished in July 2014 (about 46 flight hours prior). The bulletin was issued by Airbus Helicopters on November 28, 2013, following multiple reports of engine's remaining at idle power during practice autorotation power recoveries, despite the twist grip being moved to the VOL position. The ASB called for a modification to the engine control logic, which gives priority to the engine HMU in the event that the "forced-idle" microswitch in the twist grip fails to operate correctly. The ASB documented a series of revisions to the start selector and twist grips electrical logic. This was accomplished through modifications to the wiring harness along with the addition, dependent on model, of a series of relays.

Correct compliance of the ASB was confirmed by the group through examination, and completion of Airbus Helicopters testing procedure outlined in the maintenance document AMM 76-12-02, 4-3, and Safety Information Notice SIN 2569-S-00.

DECU/VEMD Exam

The Vehicle and Engine Multifunction Display (VEMD) was checked during the exam, and no over limits or failures were recorded for the accident flight.

The Digital Engine Control Unit (DECU) and Engine were removed, and examined by the group at the facilities of Turbomeca Engines, in Grand Prairie, Texas. The DECU appeared undamaged, and was installed and tested on a DECU loading and test bench system, configured for the 2B engine. Upon initialization, the test bench indicated that the DECU was posting a "PAN 3" error, equivalent to the error which would have been reported to the helicopter as a red GOV warning light. The DECU was then powered down, and upon second initialization the error did not post, and the test continued. The unit passed the power-up test, and the fault history file was downloaded. A total of 5 errors were recovered, the most recent occurring 500 flights prior. Due to the age of the error, the group determined that it was not related to the accident, and further examination revealed that it was most likely triggered as a result of the master switch being turned on while the helicopter was undergoing a maintenance procedure.

In an effort to replicate the PAN 3 error, the unit was allowed to cool down for 24 hours, and the test was repeated five more times. The unit passed on all subsequent tests.

Engine Exam

The engine was installed in a Turbomeca test cell, and a series of oil pressure, vibration, and coast-down time tests were performed. The engine met nominal specifications during the tests.

A series of performance engine runs were then accomplished in an effort to duplicate the loss of power scenario described by the pilots. The tests included operating the engine at varying power levels in both AUTO and mixed modes. In both modes a free turbine speed (Nf) of 100 percent was accomplished, and it took 4.9 seconds for the engine to go from ground to flight idle in mixed mode.

To test the engines response to throttle input in mixed mode, the gas generator speed (Ng) was set to 88 percent, and the throttle was moved in both directions in an effort to assess the HMU's ability to respond. In both directions, the change in Ng speed was 37 rpm; the maximum speed change allowed per the test standards was 250 rpm. When the emergency throttle was moved beyond the mixed mode (mechanical stops of the stepper motor within the HMU), the engine responded as expected by accelerating or decelerating.

The engine responded appropriately throughout the tests, and the circumstances reported by the pilots could not be duplicated.

The hydro mechanical unit (HMU) was then removed and an "HP/LP Pump and Metering Valve" acceptance test was performed utilizing a Turbomeca multi-purpose test bench configured for the 2B

engine. The unit passed all tests except for the "dynamic limiter acceleration test (ALTITUDE)". The observed error was consistent with a discrepancy of the P3 module, and according to Turbomeca representatives would have resulted in a 10% reduction in fuel flow at takeoff power, but only when the engine was operating in MAN or mixed mode.

The HMU was subsequently shipped to the facilities of Turbomeca in France for further examination under the auspices of the Bureau d'Enquêtes et d'Analyses (BEA). A bench test was performed with the same results, and the P3 module was disassembled and examined. The module was free of damage, however it was determined that the P3 capsule screw, although safety-wired, was out of adjustment. The screw was re-adjusted by 1/2 turn and the unit was again tested, this time performing within specifications.

Maintenance records revealed that the HMU had been overhauled about 50 flight hours prior to the accident, and examination of HMU overhaul records indicated that the P3 adjustment was correct during post-overhaul testing. The Turbomeca representative stated that it was not unusual for the P3 capsule to go out of adjustment while the HMU was in service.

Failure Scenario Test

In an effort to determine why the engine would not resume flight speeds after the hard landing, and whether this was related to the loss of power reported in flight, a failure-mode analysis was performed by engineers from Turbomeca France, in conjunction with the BEA and Airbus Helicopters. Testing on an exemplar HMU revealed that the behavior could be duplicated if the throttle input lever had become "declutched" from the load limiter inside the HMU. However, for this condition to exist, the following series of non-standard procedures would need to have been performed in specific order:

1 - Removal of electrical power to the helicopter on the prior flight before the engine was shutdown.

2 - Manipulating the twist grip while the electrical helicopter electrical power was still off.

3 - Starting the engine on the accident flight with the twist grip in the emergency manual control position, beyond the gate and VOL detent.

4 - Not manipulating the twist grip from VOL to IDLE and then back to VOL in deference to the requirements outlined in the autorotation preflight throttle check procedure.

Representatives from Turbomeca stated that it was possible that the declutching event occurred as a result of the hard landing; however no tests had ever been performed supporting this scenario.

Additional Information

The flight manual gave specific instructions for autorotation training procedures. Specifically, that the

power recovery should be initiated about 70 ft agl, and after the twist grip has been turned to the VOL detent, the engine should accelerate to its normal governed Nf speed, and the pilot should confirm the amber GOV and TWT GRIP lights have extinguished.

The CFI stated that he did not recall the status of the amber lights during the recovery phase prior to the hard landing, and that checking their status is not normally part of his instrument scan during the recovery maneuver. The CHP's Chief Helicopter Pilot stated that with the power recovery performed at 70 ft per flight manual recommendations, minimal time is available and the decision to focus on "flying the aircraft" is given priority over a visual scan of the GOV and TWT GRIP lights, particularly in considering the fleet's history regarding the tendency of the lights to not always extinguish.

Ten months after the accident, Airbus Helicopters issued Safety Information Notice 2896-S-00, applicable to the B, BA, BB, B1, B2, B3, D models of the AS 350. The notice covered simulated engine-off landing training, and stated the following,

"Current helicopter accident/incident statistics indicate that the greatest exposure to accidents or incidents is during simulated engine-off landing (EOL). The purpose of this Safety Information Notice is to raise the level of awareness of Flight Instructors involved in simulated EOL training and to stress on key points." The notice included an update, advising that a power recovery now be initiated as the helicopter passed through 200 ft agl.

The helicopter was equipped with an AeroComputers digital mapping system, which was capable of recording GPS based flight track information. The data from the accident flight was recovered and analyzed, and revealed a flight track that closely matched the pilot's statements.

Administrative Information

Investigator In Charge (IIC):	Simpson, Eliott
Additional Participating Persons:	Richard T Dilbeck; Federal Aviation Administration FSDO; Sacramento, CA Frédéric Aime; Bureau d'Enquêtes et d'Analyses; Lyon Greg J Draper; California Highway Patrol ; Sacramento, CA
Original Publish Date:	November 29, 2016
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB did not travel to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=90048